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Using Biosensors to Measure Behavioral and Milk Compositional Changes During Bovine Mastitis

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ABSTRACT

Automated bio-sensors were used to compare milk constituents and physical activity measures of cows experimentally infected with *Streptococcus uberis* mastitis with those of uninfected cows. Twelve late lactation Holsteins cows were placed into 6 pairs based upon milk production and parity. One cow in each pair was experimentally infected into the right front mammary gland with *Steptococcus uberis*, while the remaining cow in each pair served as an uninfected control. The automated bio-sensor system provided real-time analysis of milk fat, protein, and lactose at each milking. Pedometers were placed on the left front leg of all cows and activity was measured as number of steps taken, bouts of rest, and amount of time resting. Milk compositional data were analyzed as weighted daily averages and activity data were daily totals. Intramammary infections with *Streptococcus uberis* reduced milk yield in experimental cows by approximately 1.6 kg/day compared with control cows the first week after challenge. Lactose percentage in milk was significantly reduced by day three of infection in treatment cows compared with controls, and persisted the next three days. Percentages of fat and protein in milk did not differ between infected and uninfected cows the week after infections were induced. Total steps per day were reduced and minutes resting per day were increased in infected cows compared with control cows the week after experimental challenge. The number of resting bouts did not differ between infected and uninfected cows. These data indicated that the decreased activity in cows with mastitis was due to longer bouts of rest the first week of infection, but the number of times cows rested was comparable between infected and uninfected cows. The use of automated bio-sensors detected changes in milk components and animal activity caused by experimentally induced *Streptococcus uberis* mastitis.

INTRODUCTION

Mastitis significantly reduces production and compositional quality of milk, creating increased costs and lower returns for dairy producers. Low quality milk causes additional detriments to processors, resulting in a reduced yield of product that is of poor quality and stability. The economical profitability of the entire dairy industry is based on the quality of the bulk milk collected in the farms, therefore determined on the herd level, rather than on the health of individual animals (Leitner et al., 2011). Milk from an infected gland of an individual animal that enters the bulk milk undetected will ultimately lower the overall quality of a producer's raw product and processor's final product.

An animal with mastitis will exhibit behavioral signs and changes in the main constituents in milk (Siivonen et al., 2011). The use of daily monitoring of animal activity and milk components can be used to detect mastitis prior to onset of clinical signs (Tholen et al., 2012). This would allow the farmer to make proactive decisions regarding health and management of the animal, including the prevention of infected milk entering and tainting bulk tank milk.

OBJECTIVES

Evaluate the use of automated biosensors to detect changes in milk constituent concentrations and physical activity due to mastitis.

MATERIALS AND METHODS

Animals

Twelve late lactation Holsteins (range 179 to 258 days in milk) in the Ohio Agricultural Research and Development Krauss Dairy were paired by parity (8 primiparous and 4 multiparous cows). Cows were housed in the same free-stall pen, fed daily, and milked twice daily as a single group. One cow in each pair was experimentally infected into the right front mammary gland with *Streptococcus uberis*. The remaining cow in each pair was the uninfected control.

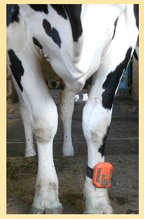
Intramammary Challenge

The bacterial strain used to create experimentally induce intramammary infections was *Streptococcus uberis* 0140J, originally isolated from clinical mastitis. Challenge inoculums were 2000 colony forming units in 1 ml sterile saline infused into the mammary quarter using a sterile 1-mL syringe fitted with a sterile teat cannula. All challenged quarters were treated by intramammary infusion with 125 mg ceftiofur hydrochloride once daily on d 4, 5,and 6 after infusion of bacteria.

Mastitis Data Collected Post-challenge

Quarter milk samples were aseptically collected from all quarters of all study cows on d 0 and 7 post-challenge for bacteriological analyses and SCC. Milk from challenged quarters was tested for enumeration of streptococci on d 1, 2, 3, and 7 after challenge. Total colony forming units of streptococci were calculated by serial dilution of milk samples plated in or on the surface of trypticase soy agar plus 0.05% ferric ammonium citrate. Plates were incubated (37° C, 18 h) aerobically prior to count determination. Total bacterial numbers were expressed as colony forming units $\log_{10}$ per milliliter. Somatic cell counts were determined on all quarter milk samples and expressed as SCC $\log_{10}$ per milliliter.

Biosensors



An automated bio-sensor system (AfiLab, S.A.E. Afikim, Isreal) provided real-time analysis of milk fat, protein, and lactose at each milking. Milk compositional data were analyzed as weighted daily averages for the 7 d after challenge. Pedometers (Afi PedometerPlus, S.A.E. Afikim, Isreal) were placed on the left front leg of all cows. Pedometers measured daily totals of number of steps taken, bouts of rest, and amount of time resting. Activity data were daily totals for the 7 d after challenge.

RESULTS

Intramammary Challenge

Each challenged mammary gland of cow infused with *S. uberis* had a somatic cell count of $>10^6$ /ml by d 3 after challenge. Five of the six cows challenged by intramammary infusion with *S. uberis* had clinical signs of mastitis in those mammary glands during the 7 d after challenge. Mean colony forming units of *S. uberis* in challenged mammary glands the 7 d after challenge are in FIGURE 1. Mammary health status of control cows did not change during the 7 d of the trial.

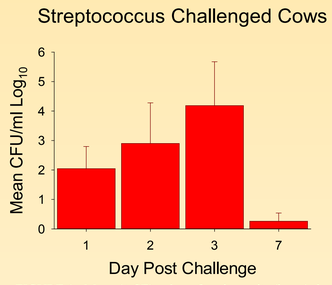


FIGURE 1. Mean (+ SE) colony forming units ($\log_{10}$/ml CFU) of Streptococcus uberis in milk of infected glands following experimental challenge in 6 cows.

Milk Yield and Composition

Mean ($\bar{x}$ ± SE) daily milk yield (FIGURE 2A) was reduced ($P < 0.05$) in challenged cows (28.5 ± 0.7 kg) compared with control cows (30.1 ± 0.5 kg) the 7 d following intramammary infusion of *S. uberis*. Mean daily lactose concentration (FIGURE 2B) was also reduced ($P < 0.05$) in milk from cows experimentally infected (4.64 ± 0.01%) compared with milk from uninfected control cows (4.71 ± 0.01%) the 7 d ost-challenge. Mean daily milk fat concentration did not differed between challenged (3.93 ± 0.05%) and control cows (3.82 ± 0.07%). Mean daily protein concentration was also similar between challenged (3.16 ± 0.02%) and control cows (3.12 ± 0.02%).

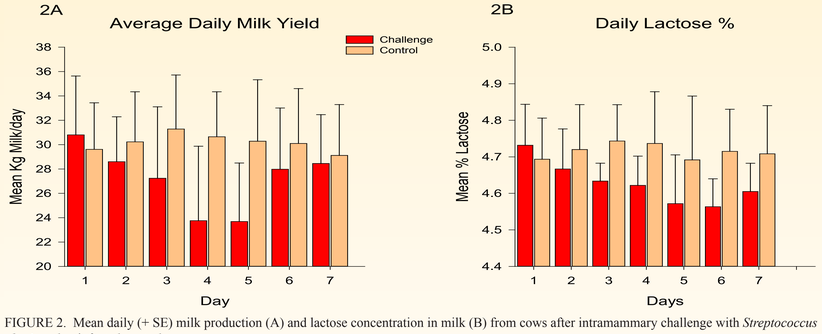


FIGURE 2. Mean daily (+ SE) milk production (A) and lactose concentration in milk (B) from cows after intramammary challenge with *Streptococcus uberis* and uninfected control cows.

Activity

The mean total daily steps (FIGURE 3A) taken by challenged cows the 7 d after challenge (172.4 ± 7.9) was reduced ($P < 0.05$) compared with control cows (203.2 ± 6.5). Conversely, the mean daily minutes spent resting (FIGURE 3B) was greater ($P < 0.05$) for challenged cows (450.0 ± 35.1) compared with control cows (298.2 ± 17.8). The mean number of daily resting bouts did not differ between challenged (12.2 ± 0.6) and control cows (11.0 ± 0.6).

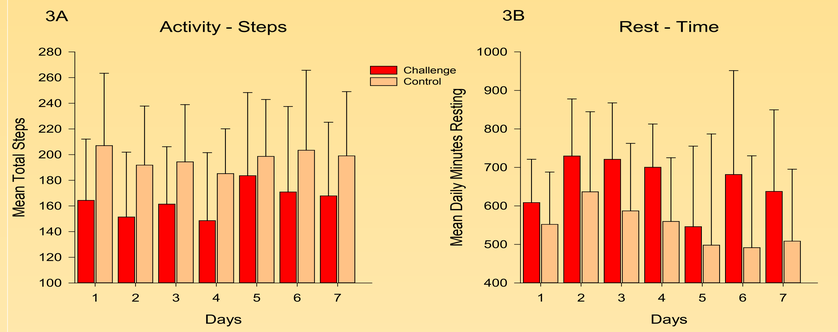


FIGURE 3. Mean daily (+ SE) steps taken (A) and time spent at rest (B) in cows after intramammary challenge with *Streptococcus uberis* and uninfected control cows.

DISCUSSION

Experimentally induced *Streptococcus uberis* mastitis caused changes in milk composition and animal behavior that was detected by an automated bio-sensor system. Experimental cows with intramammary infections exhibited a reduction in total milk yield compared with control cows. The bio-sensor system measured an approximate 1.6 kg/day loss the first week after the challenge. The real-time analysis of milk components detected lactose percentage in milk was reduced in infected cows compared with controls. This decrease was significant by day three of infection and persisted the next three days. These negative effects of mastitis on the quantity and compositional quality of milk produced are detrimental to dairy production. The ability of a commercial system to detect these changes may be valuable to the dairy producer for milk quality control.

The use of an automated pedometer system detected changes in activity and behavior in experimental cows compared with control cows the week after experimental challenge. A reduction in total steps per day and an increase in minutes resting per day in infected cows was measured by the bio-sensor. The number of resting bouts did not differ between infected and uninfected cows. These data indicate that the decreased activity in cows with mastitis was due to longer bouts of rest the first week of infection, but the number of times cows rested was comparable between infected and uninfected cows. The measured changes in physical activity in cows with mastitis, such as longer periods of resting, have a positive potential for diagnosing mammary diseases in dairy cows. Combined with milk analysis, the animal behavior data is useful to the dairy producer in formulating management strategies against mastitis and thus, enhancing milk quality.

CONCLUSION

- Mastitis caused a decrease in lactose concentration in milk of dairy cows, while fat and protein concentrations remained unchanged.
- Cows with mastitis exhibited resting bouts of longer duration compared with uninfected cows.
- Automated bio-sensors provided a real-time analysis of daily changes in milk constituents and physical activity in cows with mastitis.
- The use of automated bio-sensor systems for continuous daily measurements has a positive potential for diagnosing mammary diseases in dairy cows and formulating management strategies for enhancing milk quality.

REFERENCES

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